3 E-foresight of materials surface engineering

A.D. Dobrzańska-Danikiewicz
Institute of Engineering Processes Automation and Integrated Manufacturing Systems,
Silesian University of Technology, ul. Konarskiego 18a, 44-100 Gliwice, Poland
Corresponding author: E-mail address: anna.dobrzanska@polsl.pl

Abstract

Purpose: *The purpose of this chapter is to present the concept of e-foresight and the possibilities of its implementation in practice using the Computer Aided Foresight Integrated Research Management (CA FIRM), Virtual Organisation for Foresight Integrated Research Management (VO FIRM) and Web Platform for Foresight Integrated Research Management (WP FIRM).*

Design/methodology/approach: *The proposed methodology of the Computer Aided Foresight Integrated Research Management (CA FIRM) describes the steps to be taken within the framework of technological e-foresight in order to carry it out it in an organised, efficient, and modern manner.*

Findings: *Methodology of conducting foresight research allowing it to be carried out in an organised, efficient and modern manner.*

Research limitations/implications: *Methodology implementation allows generating a set of priority innovative technologies and determining the strategic research trends whose development will be of key importance for the country within next 20 years.*

Practical implications: *The implementation of e-foresight results into economic practice will contribute to the development of knowledge-based economy, statistical increase in the quality of technology, and continuation of sustainable development.*

Originality/value: *This chapter for the first time presents the e e-foresight idea together with associated methodology of the Computer Aided Foresight Integrated Research Management (CA FIRM), Virtual Organisation for Foresight Integrated Research Management (VO FIRM) and*

Web Platform for Foresight Integrated Research Management (WP FIRM). The "show-off effect" concept has also been introduced.

Keywords: *Manufacturing and processing; Foresight; Surface engineering*

This chapter has been also published as:

A.D. Dobrzańska-Danikiewicz, E-foresight of materials surface engineering, Archives of Materials Science Engineering 44/1 (2010) 43-50.

1. Introduction

The strategic development-related priorities of the European countries include the development of knowledge-based economy, statistical increase in the quality of technologies and sustainable development. The innovative technologies of engineering materials and biomaterials surface engineering considered as extremely development-oriented are one of the most promising technologies which can be the key contribution to the achievement of assumed strategic developmental priorities. Thus, it becomes justifiable to conduct scientific research within this subject area. In the contemporary world it is impossible to make use of the available economic, systems, technological, financial, and social potential without using cutting-edge information systems for knowledge and information management. Such management, in respect of priority innovative technologies and strategic research trends concerning materials surface engineering, can be carried out by means of foresight research used for scientific prediction and shaping of the future by gaining knowledge from domain experts, organising it and disseminating. On account of materials surface engineering area significance and importance it is justifiable to conduct foresight research related to this particular knowledge area in an organised, efficient, and modern manner.

2. Contemporary world trends

One of the key trends which significantly determine the functioning of the contemporary world is a growing percentage of advanced engineering and technology in an increasing number

of domains of everyday life. This is manifested by the fact that the access to state of the art automation developments, computerization, or satellite communication is more and more common for an average individual, which combined with already widespread command of English across the world, results in progressive globalisation and expanding cyberspace. Described factors definitely contribute to the development of information society, which not only has access to knowledge, information and information systems but also knows how to use them for the purpose of efficient and economically sound achievement of collective and individual goals. Modern society which can effortlessly gain access to any desired information is more and more aware, as a mass, of the significance of environmental issues and necessity to avoid further pollution as well as to rectify the effects of ensuing natural environment degradation. A care for natural environment is accompanied by the concept of sustainable development understood as a process of integrating systems, economic and social actions while maintaining natural balance and stability of basic natural processes, taking into consideration the interest and future of next generations.

The most important drivers which stimulate contemporary technological progress include the concept of continuous improvement, devised and implemented in the Japanese industry conditions and promoted around the world by Deming, which says that "it is never so good that it cannot get better" [1]. The consequence of a general social approval for such an approach is both higher and higher quality in various domains of social and economic life and increasing number of innovations implemented in economy as well as statistical increase in the quality of technologies implemented in the industry.

In recent decades, major changes have been observed in the relations between separate entities which make up the supply chain. The time when materials manufacturers dictated the rules is now a remote past since, at present, materials are manufactured on customer's demand and have properties demanded by the customer. In our age, it is considered a priority to increase product functionality at the expense of unjustified attachment to the type or chemical constitution of the applied material. In order to satisfy more and more sophisticated customer's needs, modern products are required to be manufactured with materials of apparently exclusive properties. This is possible by applying layers and coating with properties which are complementary to the properties of particular material.

Contemporary world is also full of various hybrids which are the consequence of combining, linking, and compiling different approaches, methods, and techniques related to problem solving. Such approach allows acquiring a new, better quality in numerous domains of life and allows the synergy effect to take place and reinforce the achieved final outcome. As part of this

trend, the tendencies towards the management and manufacturing integration have been noticed, as well as a growing popularity of hybrid technologies.

Today's world trends include also the battle against the consequences of the economic crisis and attempt to nip in the bud the behaviours which led the developed countries, thriving until quite recently, such the USA, Island, Greece, or Ireland, to serious social and economic problems. It becomes therefore necessary to use the available economic, systems, technological, financial, and social potential in the best way possible in order to take advantage of arising opportunities while avoiding at the same time the risks by applying scientific prediction and shaping of the future [2, 3, 4].

The trends which occur in the contemporary world, presented in this part of the chapter and considered most important by the Author, may be a key factor to the shaping of the world's face and further directions of development.

3. Importance of materials engineering and materials surface engineering

Materials engineering is one of several most development-oriented scientific and technological areas in the contemporary world, constituting at the same time one of the most significant elements of science, science and technology, and innovative policy of Poland within the framework of knowledge-based economy. The group of advanced engineering materials with the best prospects of development within the next 20 years certainly includes the following groups of materials: nanomaterials, biomaterials, infomaterials, light metals alloys, and graded materials [5, 6]. The asset of nanomaterials is their extremely fine-grained structure guaranteeing mechanical as well as physical and chemical properties which cannot be obtained with any other methods. The future of biomaterials is connected with the development of biomimetic materials imitating the behaviour and functioning of nature and of the materials allowing replacing natural tissues and/or human organs either directly or with the use of properly designed appliances. Informaterials, which include the most advanced intelligent and self-organising materials, also belong to the group of the most prospective materials. The materials which play a crucial role, next to the composite materials, in the designing and use of modern

means of transport are light metals alloys. Functionally and tool graded materials, in which the chemical constitution, phase composition, and structure or arrangement of atoms changes gradually along with their position (in a continuous or discrete manner) also have exceptional and specific properties [7, 8].

The development of materials engineering is not only the national but first of all the European Union's developmental priority, which have been included in the European Community's 7th Framework Programme 2007 to 2013 (FP7) for research, technological development and implementations. The detailed programme *CAPACITIES* in FP7 concerns guaranteeing the European Union's competitiveness and maintenance of productive potential, essential enhancement of industrial research, and implementation of new solutions to improve the current productive potential. The detailed programme *IDEAS* in FP7, on the other hand, intends to support the most creative, interdisciplinary scientific frontier research. The main line of development of materials engineering and production methods has been covered by the subject *"Nanosciences, nanotechnologies, materials and new production technologies"* of the detailed programme *COOPERATION* in FP7. The results of research conducted as part of the Europe's technological Foresight in the 5th and 6th European Community's Framework Programme and announced in the reports on implementation of the projects *The Future of Manufacturing in Europe (FutMan)* and *Manufacturing Visions The Futures Project (ManVis)* have been used in order to define the detailed assumptions of FP7 in the scope of materials and production methods. The most important of the selected future trends include: development of new engineering materials for expected applications, simplification of engineering materials production processes, and alternative opportunities for new production processes development in respect of new engineering materials. Among the compatible or alternative methods of accomplishing the anticipated trends one can distinguish: specialisation, convergence, and integration.

The generalisation of the European Foresight research results concerning different new materials and different material processes technologies is to anticipate the production of materials with properties demanded by the customer [9]. The necessity of producing engineering materials and biomaterials on demand, arising more and more often, in order to meet the complex set of specific requirements defined by the customer, dramatically changes the method of materials designing in general and the product material designing. At present, materials with properly formed structure guaranteeing the required set of physical and chemical properties have to be provided on demand of the product manufacturers. This approach

replaces traditional choice-making based on the materials with the offered structure and properties, choice of material which is closest to the expectations, however, which does not meet them whatsoever, thus being the choice of a lesser evil. The current tendencies force therefore the classification of engineering materials in respect of their functional characteristics. In this view, the type, and especially the chemical constitution of the material used, is of a minor importance, while product functionality gains greater importance. At present, the materials engineers participate in the product designing process, and the product manufacturers have to meet the imposed requirements as the effect of multi-criteria optimization of structure, properties, mass, product manufacturing and use costs, as well as ecological compatibility with natural environment, etc. It is therefore fundamental to make a change in the assessment of engineering materials role as they can no longer be perceived as the goods in themselves with applications sought for them, and the new engineering materials market can no longer be the manufacturer's market. Offering materials which are currently in stock regardless the users' needs is out of question now. The manufacturers' market has ended irretrievably. The new engineering materials and production processes are subjected to the customer's needs and product functional features. The production of materials which satisfy the needs of market product manufacturers in due time and place is the priority of new materials technologies and production processes as they are complementary base technologies used to improve the existing solutions, alternative technologies applying synergy of various solutions and original technologies aiming at developing completely new solutions.

When writing on the significance of the materials engineering in its broad context, which constitutes one of the most important elements of science, science and technology, and innovative policy of Poland, the importance of its component known as surface engineering should be emphasized. Very often, the functional properties of many products and their elements depend partially or mainly on the surface layer structure and properties and not only on their physical and chemical properties or the possibility of transferring the mechanical load through the entire cross section of the element. Therefore, as a result of proper selection of the element's material together with its structure and properties formation processes as well as surface layer type and technology, which guarantee required functional properties, it is possible to put together the manufactured element's core and surface layer properties in the most favourable manner. It is thus not surprising that materials surface engineering, including surface treatment and coating, is one of the most dynamically developing sectors of economy in many technologically advanced countries. As an example, according to reference data of 2008,

8-10% of German economy was accomplished in this very industrial sector. With a large measure of probability the analogous phenomenon will soon occur in a rapidly developing Polish economy. Surface treatment and coating in its wide context are carried out in almost each manufacturing sectors of the industry including the automotive, machine building, tool construction, mechatronic, metallurgical, electrotechnical, electronic, plastics, aircraft, medical equipment, sanitary devices, jewellery, precision, construction, and other industries. Engineering materials and biomaterials surface engineering is undoubtedly one of those domains which are promising and can potentially become a key contribution to the country's economic growth.

For the accomplishment of a long-term strategy of production which will respond in a flexible manner to continuous change in the customers' preferences, the Polish enterprises, following the example of the countries operating within the so-called old European Union, should put pressure on constant development of advanced manufacturing technologies and search for innovative solutions. The level of technological novelties implementation and increase in the quality of applied technologies within this scope is definitely unsatisfactory, especially when referring to small and medium-sized enterprises (SMEs), of which expenditures on development are inconsiderable. Thus a need arises to chart the course of action for the SMEs, which will positively contribute to their market success and consequently will be a key contribution to the statistical increase in the quality of the technologies implemented in the Polish industry. It should be highlighted that the examined issue does not concern solely the cutting edge technologies applied by model enterprises which are often referred to when discussing new technologies. It is much more important to focus on the critical need of increasing the average level of technology implementation by statistical majority of manufacturers, which is crucial for the quality and stability of a statistical majority of products launched into the market and it substantially determines competitiveness of the country's economy.

4. E-foresight

When carrying out the foresight research related to materials surface engineering in practice, the problems and difficulties have been encountered which urged the Author of this chapter to conduct scientific research aiming at organising, improving and updating the process of carrying out foresight research. Such a large scale of research planned to be conducted has become the major driving force behind the implementation of improvements. Generally, 14 subject areas have been analysed within the framework of foresight research on materials surface engineering.

At the initial research stage, about 500 technologies have been analysed, about 150 of which have been qualified for detailed analysis. As part of the research, three survey iterations have been planned, addressed to top-class experts selected from the scientific, business, and public administration environments. It has been planned that 210 filled in surveys will be obtained in each of three foresight research iterations – 630 in total [10]. The necessity has therefore arisen to develop methodology and information technology which would organise, improve, and update conducted foresight research. This is how the e-foresight idea emerged in relation to already known and commonly used concepts [11, 12]: e-management, e-business, e-commerce, e-banking, e-logistics, e-services, e-administration, e-education, which always refer to the performance of particular activities using the computer networks, especially the Internet.

4.1. E-foresight idea

E-foresight means conducting foresight research using the Internet. E-foresight is orientated to support the activities of two beneficiaries. The first group consists of foresight researchers, who can perform their work at any time and in any location, which combined with teleworking contributes to giving equal opportunities on the labour market as it allows the persons working from home, including mothers raising small children and disabled persons, to join the team of project researchers. The other group of beneficiaries are the domain experts, direct participants of the conducted survey, selected from the scientific, business, and public administration environments, who can work according to the principle: *"I participate with my laptop in the foresight research at the time and place which are most convenient to me"*, thus contributing to a quicker and more effective acquiring of indirect and final research results.

4.2. Computer Aided Foresight Integrated Research Management CA FIRM

The Computer Aided Foresight Integrated Research Management (**CA FIRM**) methodology describes the steps to be taken within the framework of the e-foresight technological research in order to carry it out in an organised, efficient, and modern manner. Such *organising* is achieved by describing in detail the order of what needs to be done and

how, so that the foresight research is conducted successfully in practice, which is of great significance if we take into consideration an inconsiderable number of national publications on this subject. Carrying out the foresight research in a more *efficient* manner is achieved by speeding it up, elimination of the "show-off effect", and occurrence of the synergy effect resulting from the integration of the foresight research. The foresight research conducted in a *modern* way is accomplished through the use of information technology, including the Web Platform, virtual organisation, databases, and neural networks, which fits into the most dominant world trends according to which the racing process of computerization in respect of newer and newer domains of life is observed.

The key question which will we will be able to answer as a result of implementing the CA FIRM methodology is following:

Which of the technologies applied in a particular research field belong to the set of priority innovative technologies and the development of which strategic research trends in a particular research field will be of key importance for the country within next 20 years?

In order to answer the above research question, it is necessary to execute the following **steps** of the CA FIRM arranged on a serial and parallel basis:

- Division of a wide research field covered by the foresight subject into detailed subject areas;
- Performing of three iterations of expert opinion research by electronic way;
- Preparation of the static statements presenting expert opinion research results;
- The dendrological matrix of technology value construction;
- The meteorological matrix of technology value construction;
- The matrix of strategies for technologies construction;
- The neural networks creation and training using data received from experts;
- Preparation neural networks aided three alternative version of future events scenarios, respectively: optimistic, neutral and pessimistic ones;
- Creation of the Critical Technologies Book including the pool of Technology Roadmaps and Technology Information Sheets;
- Open public debate initiation and animation;
- Useful assessment of the modern information technology including Virtual Organisation, Web Platform and Neural Networks into the foresight process realisation.

The CA FIRM methodology is dedicated to the computer aided foresight research on materials surface engineering. The implementation of the proposed approach allows the

technological foresight on materials surface engineering future to be carried out in an organised, efficient and modern manner, and, in particular, allows determining priority innovative technologies and strategic development trends within this research field. It should be noted, however, that this methodology, due to its universal nature, can be without any difficulties implemented to carry out any technological foresight concerning the future of any domain of knowledge. The computer tool allowing the CA FIRM to be conducted from the technical aspect is the author Web Platform for Foresight Integrated Research Management (WP FIRM). In order to achieve the e-foresight objectives it is also necessary to create a Virtual Organisation for Foresight Integrated Research Management (VO FIRM) which allows gathering, organising, selecting, and managing explicit and tacit knowledge in cyberspace.

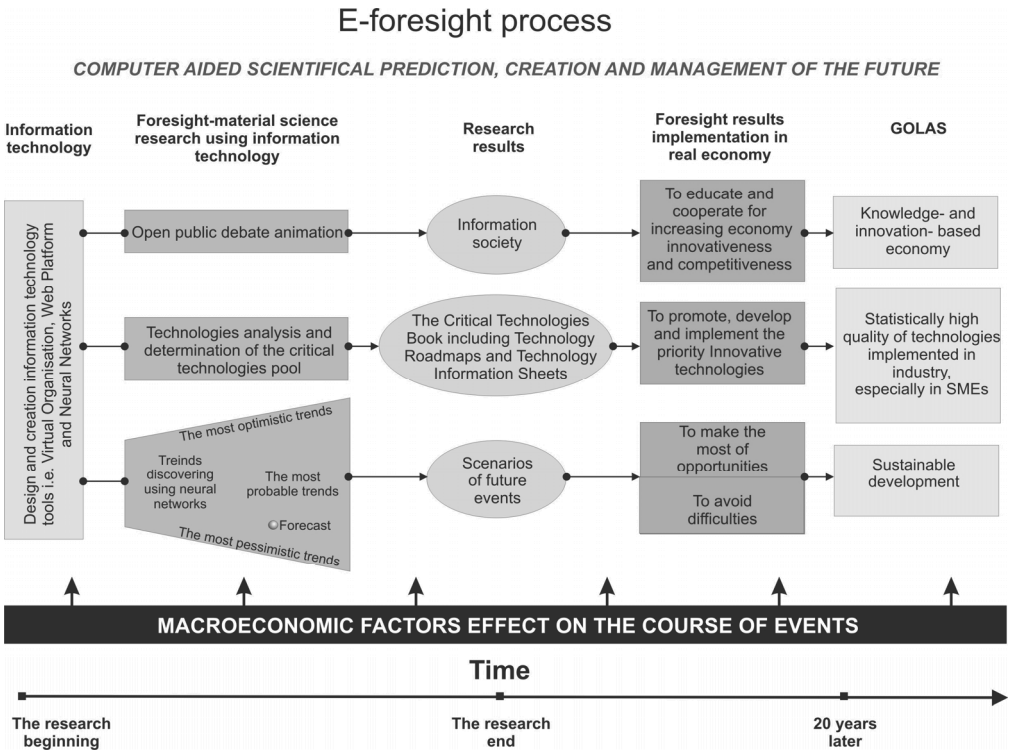

Figure 1. *E-foresight process*

The e-foresight process including the technical basis indispensable for the commencement of appropriate research, the types of the VO FIRM virtual organisation activity with the use of WP FIRM Web Platform, research results, implementation of foresight results in the economic

reality, and strategic objectives that those activities are accompanied by have been presented in Figure 1. Attention should be paid to the distribution of the mentioned elements across the time scale and to the constant impact of macroeconomic factors on the course of events.

Due to the implementation of the CA FIRM methodology it becomes possible to achieve the main objectives of technological foresight in an organised, efficient, and modern manner as well as to specify which of the technologies applied in a particular research field belong to the set of priority innovative technologies and the development of which strategic research trends in a particular research field will be of key significance for the country within next 20 years. The developed methodology is an integrated approach which allows gaining explicit and tacit knowledge from the top-class experts selected from the scientific, business, and public administration environments during the performance of three survey iterations. The proposed approach uses the synergy effect and eliminates unfavourable psycho-social phenomenon called by the Author of this chapter as the "**show-off effect"** which is manifested during direct meeting of people which serves to exchange views on a specific subject and consists in the fact that people are orientated to show themselves to their best advantage and promote themselves instead of sharing their knowledge.

4.3. Virtual Organisation for Foresight Integrated Research Management VO FIRM

The concept of virtual organisation introduced in 1992 by W. Dawidow and M. Malone [13] have been modified, improved, and developed over years, which, however, has not resulted in the formulation of one commonly acceptable concept base.

The deliberations present in the literature on the subject area have resulted in the establishment of two trends reflecting different approaches to virtual organisation [14]: process-based and structural. The process-based approach presents the organisation from the functional point of view, as an operation mechanism, area of activity, or approach towards organisation management which focuses on actions and behaviours [15]. On the other hand, the structural approach, presented much more often, concerns the components of an organisation, their characteristics, and dependencies between them.

The Virtual Organisation for Foresight Integrated Research Management (VO FIRM), created for the achievement of e-foresight objectives, is part of the structural trend and signifies

a system of elements, formed on the basis of voluntary principle, functioning dynamically and flexibly structuralised. This system of elements is of a task nature, orientated towards particular objectives, coordinated by means of information technology, allowing tacit and explicit knowledge to be gathered, organised, selected, disseminated, and managed in cyberspace.

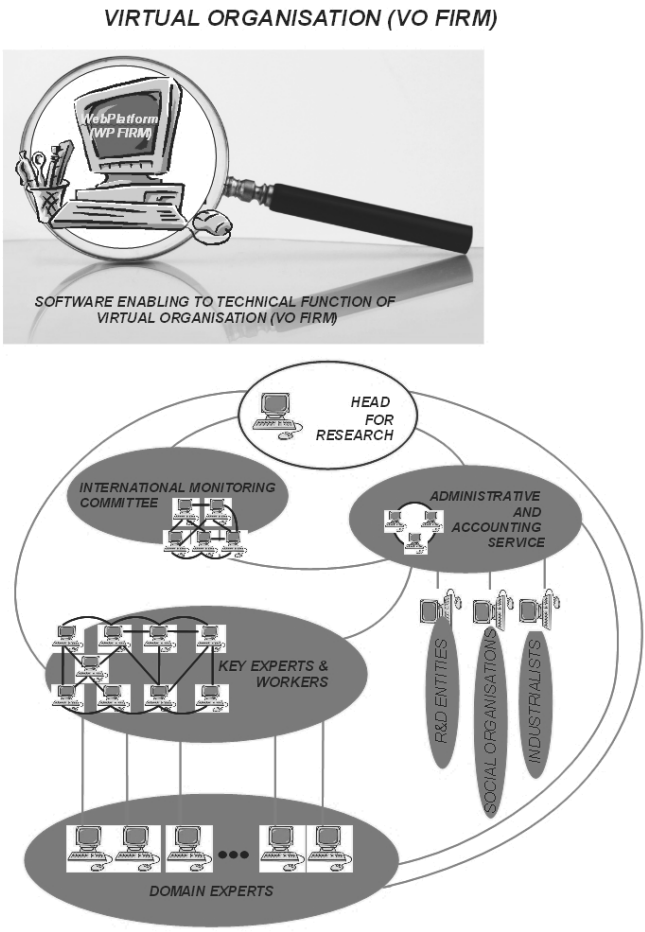

Figure 2. *Organisational chart for VO FIRM*

The VO FIRM is set up to accomplish a long-term all-society objective which is a closer relation between science and economy and development of information society, thus increasing the importance of knowledge-based economy (KBE), seeking sustainable development and statistical increase in the quality of technology. The VO FIRM is indispensable to carry out the

technological foresight aiming at identifying priority innovative technologies and strategic research trends in respect of the analysed research field. A general organisational chart for the Virtual Organisation for Foresight Integrated Research Management – VO FIRM, has been shown in Figure 2.

The Virtual Organisation Management – VO FIRM as per devised concept of its functioning in cyberspace is carried out using the following modules of the Web Platform – WP FIRM:

- Experts' surveying;
- Database on experts;
- Newsletter;
- Information management;
- E-mail management;
- Finance and documentation management,
- Contract export/import from/to the university contracts system.

4.4. Web Platform for Foresight Integrated Research Management WP FIRM

The Web Platform for Foresight Integrated Research Management – WP FIRM developed from scratch on the basis of the author concept is a computer tool allowing the e-foresight objectives to be met and the virtual organisation VO FIRM to be managed in cyberspace. The Web Platform WP FIRM serves to provide the conditions for the performance of tasks by the research team of the foresight project researchers. In addition, the WP FIRM Web Platform aims at providing work comfort for the domain experts selected from the scientific, business and public administration environments, thus allowing them to work according to the principle: *"I participate with my laptop in the foresight research at the time and place which are most convenient to me"*. Thanks to the WP FIRM Web Platform it is also possible to easily disseminate information concerning the progress of conducted work and stimulate public debate on the foresight subject.

The list of activities which can be performed in cyberspace owing to technical possibilities provided by the WP FIRM Web Platform includes the following elements:

- Conducting large-scale questionnaire surveys;
- Free use/collation of information included in the database on experts;
- Receiving subscription news concerning the project realisation in the form of a *newsletter* by individuals from the world of industry, science and public administration;
- Managing information collected in the computer database;
- Quick exchange of Internet correspondence with experts whose names are in the computer database;
- Managing project finances, contracts, and documentation;
- Immediate data transfer from/to a compatible university contracts system;
- Obtaining information used for developing the database on experts and managing the data concerning particular domain experts in a quick and effective manner;
- Tracking the events concerning the Project on an ongoing basis by every outside observer, both by viewing the website as well as active participation in an online public debate.

Figure 3. *An exemplary page of the WP FIRM*

At present the WP FIRM Web Platform can be viewed as a "living organism" as it is subjected to constant development, updates and modifications. The platform reacts dynamically to the user' needs arising and changing over the course of foresight research realisation. The changes are implemented on an ongoing basis and aim to maximize performed tasks and functions, streamline the user interface, enhance data storage safety, increase resistance to disturbances, adapt to the existing and commonly applied IT solutions. The main page of the WP FIRM Web Platform, tested and verified for the purposes of materials surface engineering foresight, has been presented in Figure 3.

5. Conclusions

The innovative technologies of materials surface engineering as extremely development-orientated belong to the most promising technologies, which can become a key contribution to the accomplishment of strategic developmental priorities of the European countries including the development of knowledge-based economy, statistical increase in the quality of technology and sustainable development thus substantiating the research conducted in this field. When carrying out the foresight research concerning materials surface engineering in practice, the problems and difficulties have been encountered mainly due to a large scale of planned activities, which triggered scientific research aiming at organising, improving, and updating the conducted foresight research process. As a response to a justifiable necessity of devising methodology and information technology for this purpose, the e-foresight idea has emerged which signifies carrying out the foresight research using the Internet. E-foresight is orientated to support the activities of two beneficiaries: the foresight project researchers and the domain experts participating directly in the conducted questionnaire surveys according to principle: *"I participate with my laptop in the foresight research at the time and place which are most convenient to me",* thus contributing to a quicker and more effective acquiring of indirect and final research results. In order to achieve the objectives of technological e-foresight, which come down to the identification of priority, innovative research technologies and strategic trends in respect of the analysed research field, the Computer Aided Foresight Integrated Research Management – CA FIRM methodology has been developed. The implementation of the devised methodology into practice is possible thanks to the creation

of the Virtual Organisation for Foresight Integrated Research Management (VO FIRM), based on the voluntary principle, which constitutes a system of elements orientated towards particular objectives, coordinated by means of information technology, allowing tacit and explicit knowledge to be gathered, organised, selected, disseminated, and managed in cyberspace. The computer tool which enables the achievement of such defined objectives and aims from the technical aspect is the Web Platform for Foresight Integrated Research Management – WP FIRM, developed from scratch on the basis of the author concept.

References

1. M. Sokovic, D. Pavletic, K. Kern Pipan, Quality Improvement Methodologies – PDCA Cycle, RADAR Matrix, DMAIC and DFSSM, Journal of Achievements in Materials and Manufacturing Engineering 43/1 (2010) 476-483.
2. D. Loveridge, Foresight, The Art and Science of Anticipating the Future, Taylor & Francis, New York, 2009.
3. L. Georghiou, J.C. Harper, M. Keenan, I. Miles, R. Popper, The handbook of technology foresight. Concepts and Practice, Edward Elgar Publishing Ltd., United Kingdom, 2008.
4. L.A. Costanzo, R.B. Mackay, Handbook of Research on Strategy and Foresight, Edward Elgar Publishing, 2009.
5. J. Dobrzański, A. Zieliński, M. Sroka, The influence of simultaneous impact of temperature and time on the properties and structure of X10CrWMoVNb9-2 steel, Journal of Achievements in Materials and Manufacturing Engineering 34/1 (2009) 7-14.
6. A. Akinci, Mechanical and morphological properties of basalt filled polymer matrix composites, Archives of Materials Science and Engineering 35/1 (2009) 29-32.
7. L.A. Dobrzański, K. Lukaszkowicz, K. Labisz, Structure, texture and chemical composition of coatings deposited by PVD techniques, Archives of Materials Science and Engineering 37/1 (2009) 45-52.
8. J. Kopac, Achievements of sustainable manufacturing by machining, Journal of Achievements in Materials and Manufacturing Engineering 34/2 (2009) 180-187.
9. A.D. Dobrzańska-Danikiewicz, Main assumptions of the foresight of surface properties formation leading technologies of engineering materials and biomaterials, Journal of Achievements in Materials and Manufacturing Engineering 34/2 (2009) 165-171.

10. A.D. Dobrzańska-Danikiewicz, The methodological fundaments of development state analysis of surface engineering technologies, Journal of Achievements in Materials and Manufacturing Engineering 40/2 (2010) 203-210.
11. J. Kisielnicki, MIS. Management Information Systems, Placet, Warsaw, 2008 (in Polish).
12. M. Hasan, E. Harris, Entrepreneurship and innovation in e-commerce, Journal of Achievements in Materials and Manufacturing Engineering 32/1 (2009) 92-97.
13. W. Dawidow, M. Malone, The Virtual Coropration, Harper Business, New York, 1992.
14. W. Werther, Structure-Driven Strategy and Virtual Organization Design, Business Horizons 42/2 (1999).
15. J. Burn, P. Marshall, M. Burnett, E-Business and the Virtual Organisation, Butterworth-Heinneman, Oxford, 2001.